NITROGEN FERTILIZATION IMPROVES QUANTITY AND QUALITY OF ORGANIC MATTER IN A GRASSLAND SOIL

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BACKGROUND:

- Sustainability of agriculture production is linked to soil quality which is a function of organic matter.
- On cultivated lands, soil, crop and fertilizer management practices, which increase the input of C to soil and/or prevent loss of C and N from soil, can build organic C and N in soil.
- The land use change from crop land to perennial grass cover can increase the soil organic C (SOC) levels by sequestering more C from the atmosphere.
- In the Prairie Provinces, forage grasses play a major role in the production of beef, and are also a component of sustainable agricultural cropping systems.
- Good forage stands can increase organic C in soil, and consequently soil can function as a net sink of atmospheric C.
- The storage of C and N in soil is related to the amount of crop residues, which in turn is associated with crop yield.
- On perennial grasslands, where tillage can be avoided, forage productivity can be increased considerably with N fertilization on most soils in the Prairie Provinces.

OBJECTIVE:

To determine the change in quantity and quality of organic C and N in a grassland soil receiving N fertilization for 27 years.

MATERIALS AND METHODS:

Location/Soil: Crossfield, Alberta, Canada (thin Black Chernozem loam soil)
Treatments: - N rates - 0, 56, 112, 168, 224 and 336 kg N ha^{-1}
- N source – Ammonium nitrate (applied annually on surface to smooth bromegrass – *Bromus inermis* Leyss.)
- Duration - 27 years (1968 to 1994)

Annual Precipitation: 450 mm
Growing Season: May to September
Statistical Design: Randomized complete block (six replications)
Depths of Soil Sampling: 0-5 cm (Layer 1), 5-10 cm (Layer 2), 10-15 cm (Layer 3) and 15-30 cm (Layer 4)
Data Recorded: Total organic C (TOC), total organic N (TN),

light fraction organic C (LFOC), light fraction
N (LFN) and amino acid C and N, and
ammonium-N in soil in 1994
Dry matter yield (every year)

RESULTS:

Hay Yield and C Removed (Figure 1)

- Dry matter hay yield was increased substantially by application of N, and so did the amount of C removed in hay.
- Compared to the zero-N control, amount of C removed in hay was increased by 31.71 and 35.22 Mg C ha^{-1} at 112 and 224 kg N ha^{-1}.
- However, mass of C removed per unit of applied N was decreased from 14.9 to 8.28 kg C kg N-1 ha^{-1} yr^{-1} when N rate was increased from 112 to 224 kg N ha^{-1}.

TOC and LFOC in Soil (Figures 2 and 3)

- Concentration and mass of TOC and LFOC in soil was increased markedly with N fertilization. The increase in TOC and LFOC due to N fertilizer was much more in the 0-5 cm layer than in the other soil layers.
- Mass of TOC and LFOC in 0-15 cm soil was increased by 11.47 and 19.35 Mg C ha^{-1}, and that of LFOC was increased by 7.17 and 14.10 Mg C ha^{-1}, respectively, at 112 and 224 kg N ha^{-1} compared to the zero-N control.
- Ratio of LFOC to TOC in soil was also increased by application of N fertilizer

TN and LFN in Soil (Figures 4 and 5)

- Concentration and mass of TN and LFN in soil was increased with application of N fertilizer. The increase in TN and LFN due to N fertilizer was much more in 0-5 cm layer than in the other layers.
- Mass of TN in 0-15 cm soil was increased by 0.95 and 1.92 Mg N ha-1, and that of LFN was increased by 0.37 and 0.87 Mg N ha^{-1}, respectively, at 112 and 224 kg N ha^{-1} rates compared to zero-N control.
- Ratio of LFN to TN in soil increased with increasing N rate.

Amino Acids in Soil (Figures 6, 7 and 8; Tables 1 and 2)

- Concentration and mass of amino acids C and N in soil was increased with application of N fertilizer. The increase in amino acids C and N from N fertilization was much more in 0-5 cm layer than in the other layers.
- Mass of amino acids C in the 0-15 cm soil was increased by 1.42 and 2.48 Mg C ha^{-1} and that of amino acids N by 0.44 and 0.76 Mg N ha^{-1}, respectively, at 112 and 224 kg N ha^{-1} rates compared to the zero-N control.
- Concentration and mass of the 17 amino acids C and N in different soil layers and their responses to applied N varied with the amino acid.

Ammonium-N in Soil (Figure 9)

- Concentration and mass of ammonium-N in soil increased with application of N fertilizer, but the increase was much more in 0-5 cm layer than in the other layers.

Table 1. Mass of amino acid C in the 0-5 cm soil layer

No.	Amino acid	Mass (Mg C ha^{-1}) in soil at N rates (kg N ha^{-1})			Significance [a]
		0	112	224	
1	Aspartic acid	0.243	0.335	0.383	***
2	Threnine	0.103	0.156	0.207	***
3	Serine	0.080	0.121	0.157	***
4	Glutamic acid	0.197	0.286	0.343	**
5	Proline	0.086	0.159	0.210	***
6	Glycine	0.117	0.167	0.205	***
7	Alanine	0.120	0.180	0.230	***
8	Valine	0.100	0.162	0.218	***
9	Isoleucine	0.083	0.131	0.177	***
10	Leucine	0.126	0.219	0.309	***
11	Norleucine	0.000	0.000	0.000	
12	Tyrosine	0.036	0.061	0.094	***
13	Phenylalanine	0.088	0.148	0.214	***
14	Histidine	0.033	0.058	0.072	***
15	Lysine	0.111	0.161	0.203	***
16	Ammonia	0.000	0.000	0.000	***
17	Arginine	0.064	0.103	0.134	***
	Total	1.587	2.447	3.154	***

[a]*, **, and *** indicate the treatment effect being significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectively.

Table 2. Mass of amino acid N in the 0-5 cm soil layer

No.	Amino acid	Mass (Mg N ha^{-1}) in soil at N rates (kg N ha^{-1})			Significance [a]
		0	112	224	
1	Aspartic acid	0.071	0.098	0.112	***
2	Threnine	0.030	0.046	0.060	***
3	Serine	0.031	0.047	0.061	***
4	Glutamic acid	0.046	0.067	0.080	**
5	Proline	0.020	0.037	0.049	***
6	Glycine	0.068	0.098	0.120	***
7	Alanine	0.047	0.070	0.090	***
8	Valine	0.023	0.038	0.051	***
9	Isoleucine	0.016	0.025	0.034	***
10	Leucine	0.024	0.043	0.060	***
11	Norleucine	0.000	0.000	0.000	
12	Tyrosine	0.005	0.008	0.012	***
13	Phenylalanine	0.011	0.019	0.028	***
14	Histidine	0.019	0.034	0.042	***
15	Lysine	0.043	0.063	0.079	***
16	Ammonia	0.285	0.351	0.408	***
17	Arginine	0.050	0.080	0.104	***
	Total	0.790	1.122	1.389	***

[a]*, **, and *** indicate the treatment effect being significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$, respectivel

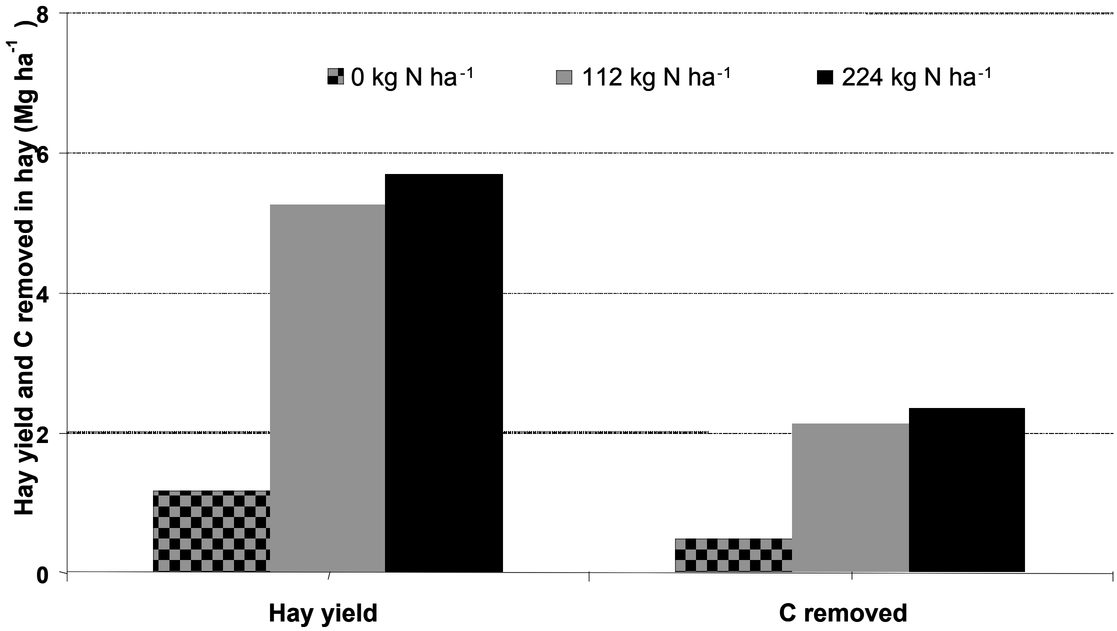

Figure 1. Bromegrass hay yield and estimated mass of C removed in hay (averaged over 19 years from 1968 to 1986).

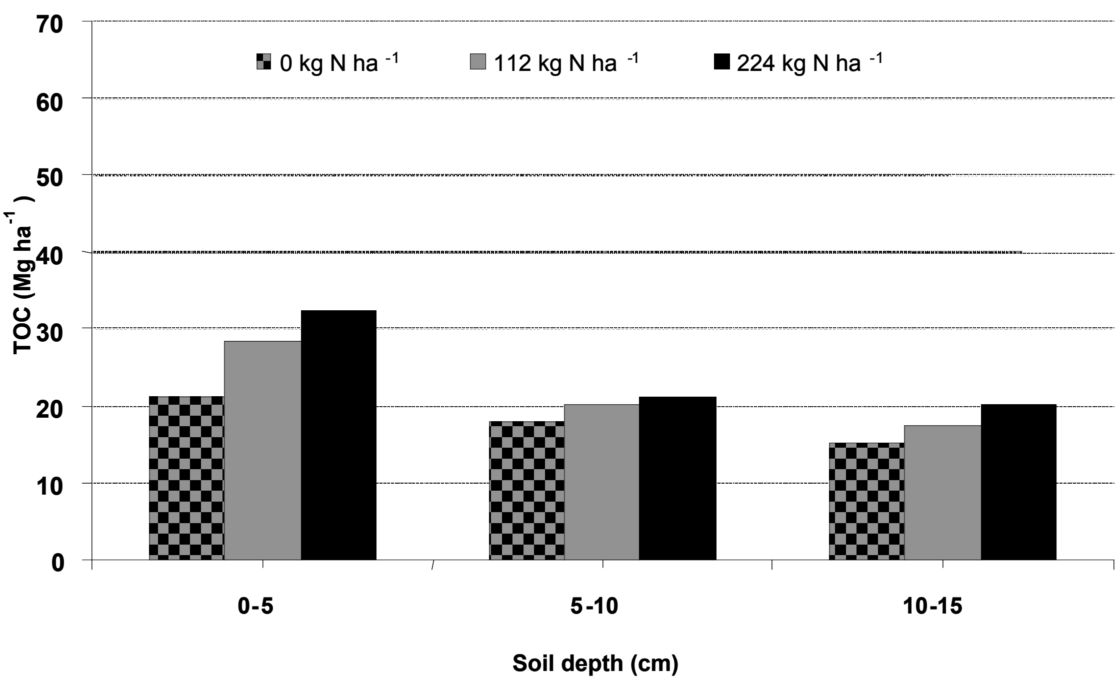

Figure 2. Mass of TOC in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta.

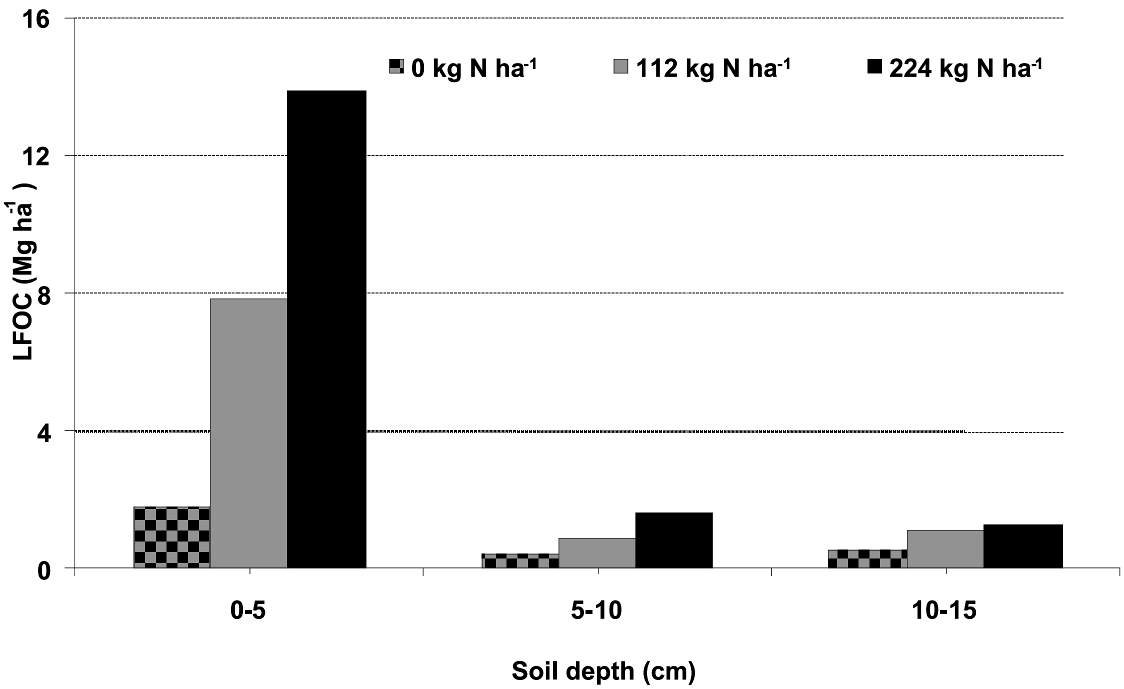

Figure 3. Mass of LFOC in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta.

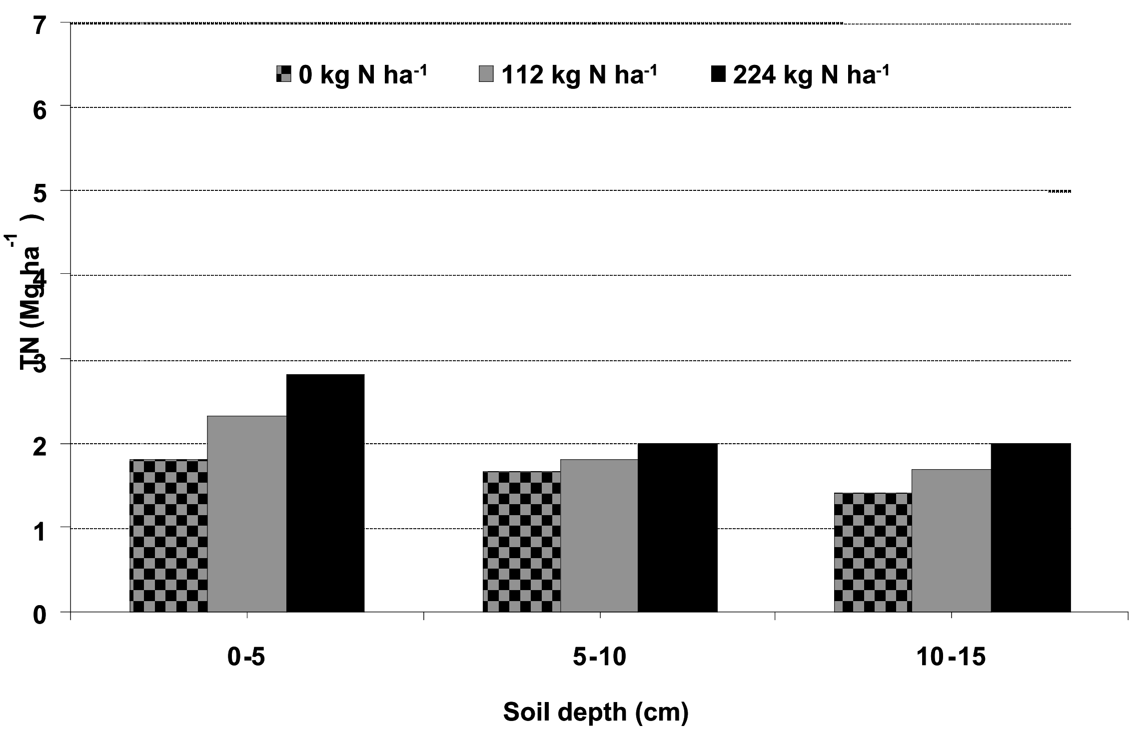

Figure 4. Mass of TN in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta.

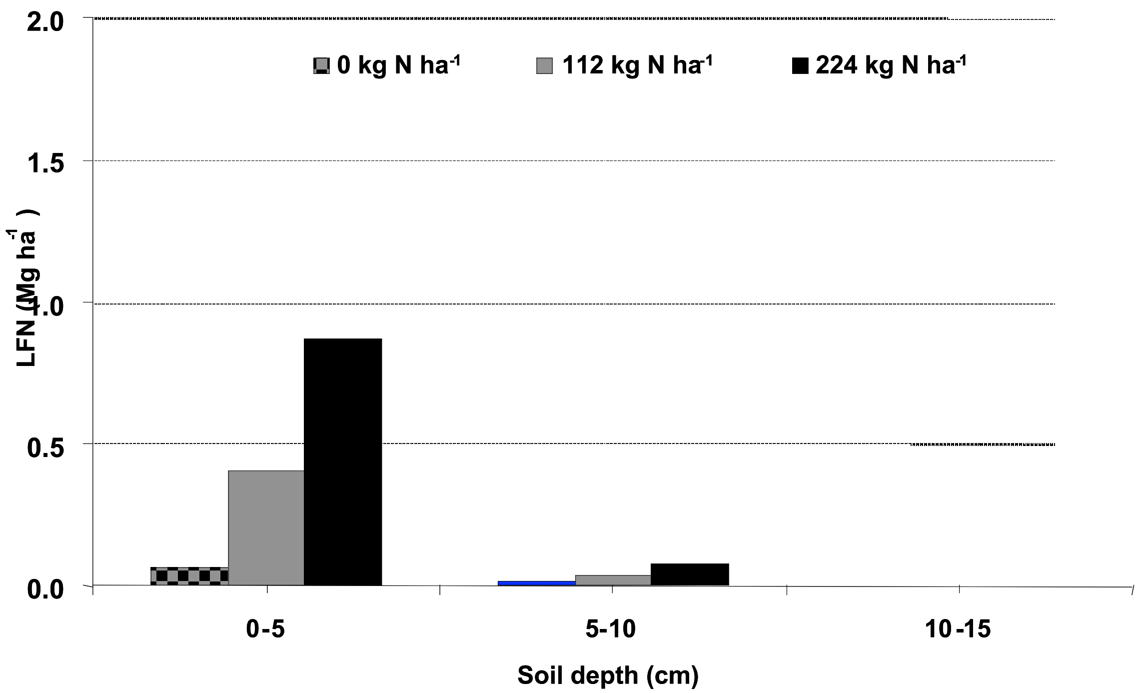

Figure 5. Mass of LFN in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta.

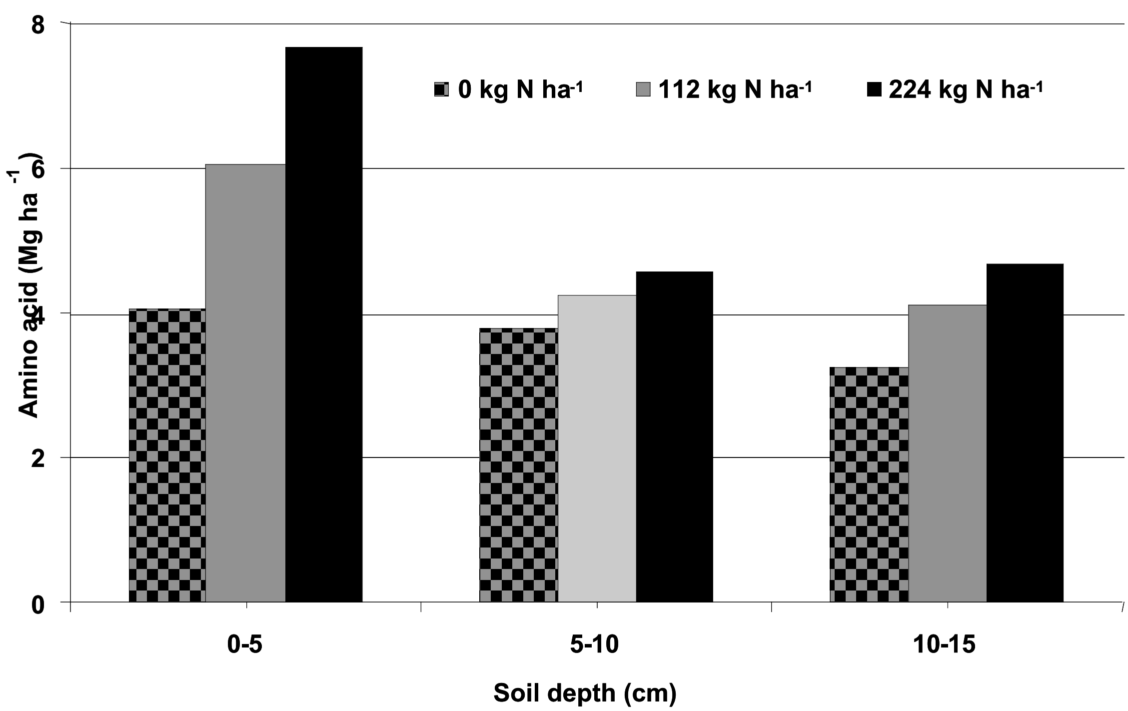

Figure 6. Mass of amino acids in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta.

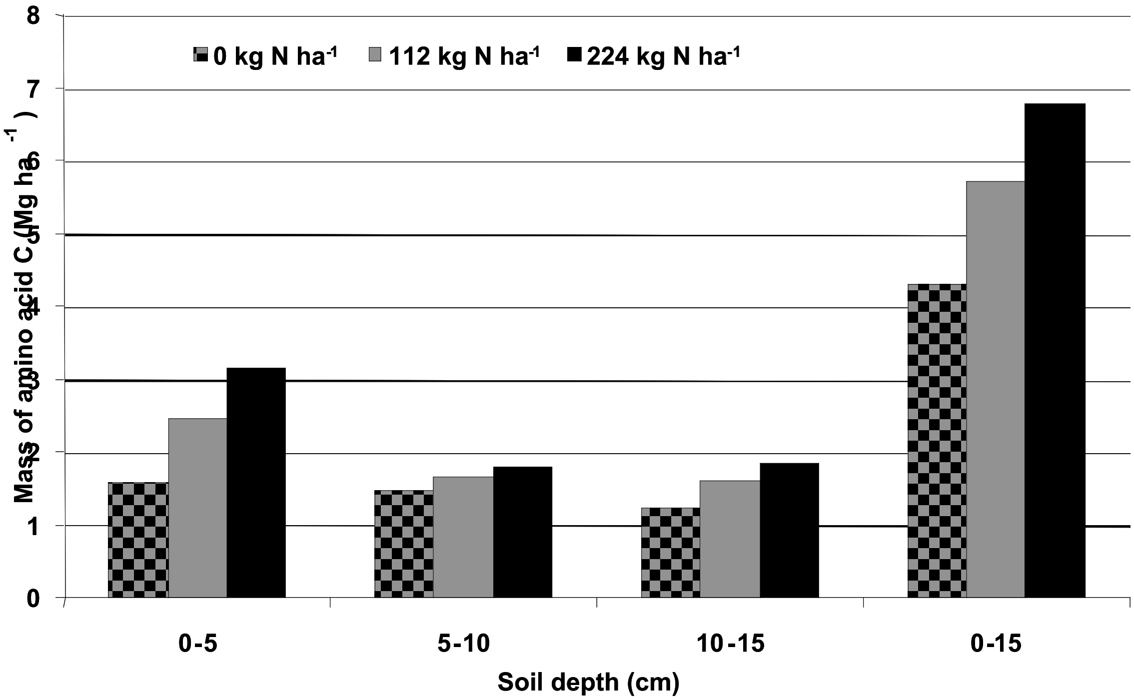

Figure 7. Mass of amino acid C in soil after 27 years (1968 to 1 994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

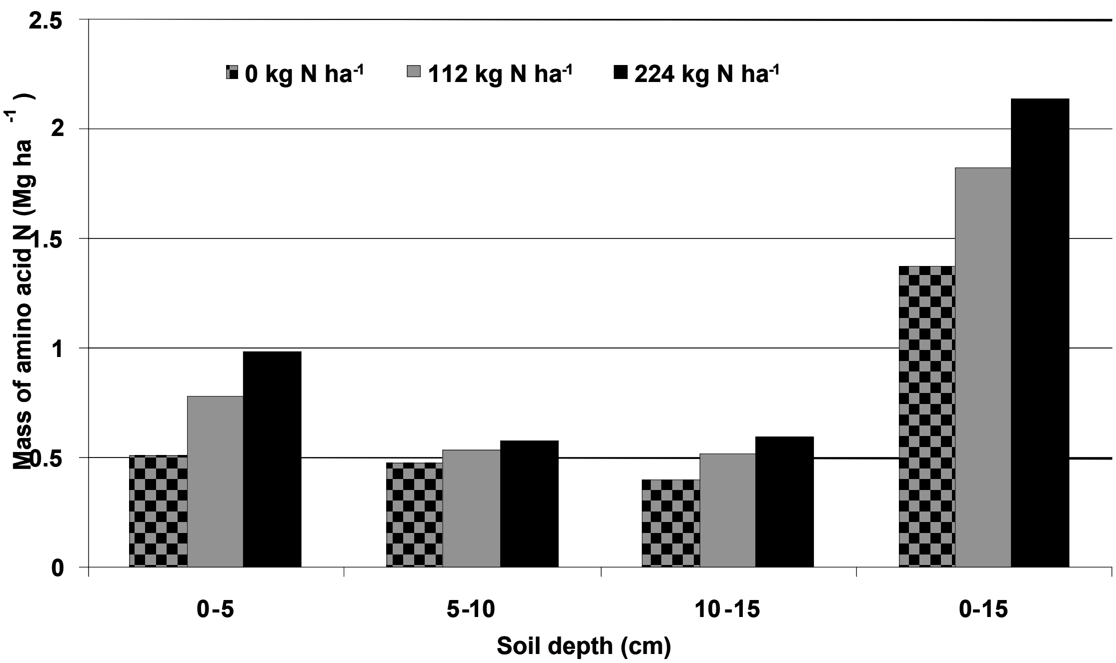

Figure 8. Mass of amino acid N in soil after 27 years (1968 to 1 994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

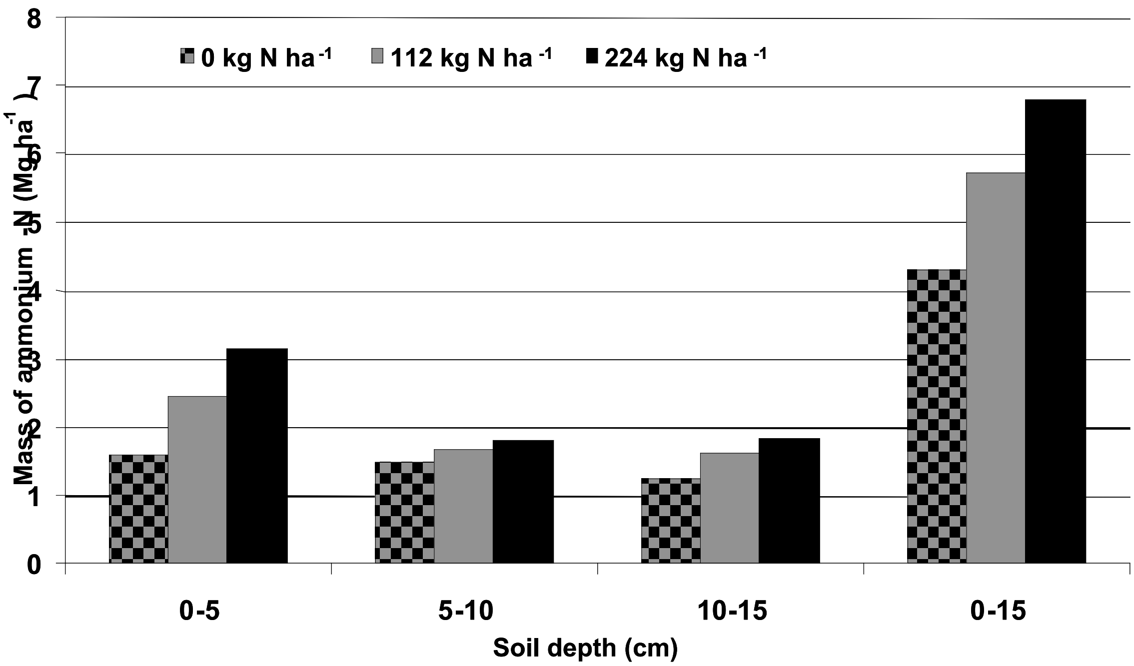

Figure 9. Mass of ammonium -N in soil after 27 years (1968 to 1994) of annual applications of ammonium nitrate to bromegrass grown as hay at Crossfield, Alberta

CONCLUSIONS:

- ✓ Long-term annual additions of fertilizer N for 27 years to bromegrass resulted in substantial increase in organic C and N in soil.
- ✓ The findings also showed marked changes in the quality of organic C and N (i.e., light fraction organic C and N, and amino acids C and N) in soil due to N fertilization.
- ✓ The implication is that grasslands can be managed by N fertilizer additions to store more C and N in soil and to improve the quality of organic matter.
- ✓ This may lessen the increase in atmospheric CO_2 concentration and release of N_20 from soil to the atmosphere, and at the same time improving nutrient release potential and tilth of soil. This would be beneficial to the environment.

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